Imageability, age of acquisition, and frequency factors in acronym comprehension

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Abstract

In spite of their unusual orthographic and phonological form, acronyms (BBC, HIV, NATO) can become familiar to the reader, and their meaning can be accessed well enough that they are understood. The factors in semantic access for acronym stimuli were assessed using a word association task. Two analyses examined the time taken to generate a word association response to acronym cues. Responses were recorded more quickly to cues which elicited a large proportion of semantic responses, and those which were high in associative strength. Participants were shown to be faster to respond to cues which were imageable or early acquired. Frequency was not a significant predictor of word association responses. Implications for theories of lexical organisation are discussed.

The present study is concerned with acronyms, a significant part of our vocabulary that has been largely neglected in word processing research. Acronyms are abbreviations of long terms or cumbersome phrases commonly formed by selecting key letters within a term or sentence (e.g., DNA from deoxyribonucleic acid, WWW from World Wide Web). As a result of this process, acronyms can have very peculiar orthographies in conjunction with unusual pronunciation patterns. Originally the term 'acronym' was coined to designate pronounceable abbreviations (e.g., NATO, RADAR) while 'initialism' was the name selected for unpronounceable abbreviations (e.g., PC, TV). However, despite this distinction acronym is the word more commonly used to refer to all abbreviations, pronounceable or not, formed as a combination of the initial letters of a term or sentence. It is in this more general sense that the word acronym is used in the present study. In addition, only acronyms constituted by a string of consonants, or vowels or a combination of vowels and consonants (e.g., BBC, EU, HIV), will be discussed here.

The formation of acronyms is not new or unique to the English language. RIP (*Requiescat in pace* – Rest in peace), for example, is an early acronym from the Latin. However, despite their historical presence in all languages, acronym formation was never prolific in the distant past. This changed dramatically a few decades ago when an increase in literacy and wealth, and advances in science and technology popularised the generation of acronyms. The latest emergence of Short Message Systems (SMS) has boosted the creation and use of acronyms at a rate never experienced before.

Research on how acronyms are processed is scarce. The few studies that have looked at acronym reading and recognition processes have been mainly interested in the lexicality status of acronyms, the question of interest being whether acronyms storage and processing is similar to that of mainstream words (Besner et al., 1984; Brysbaert, Speybroeck and Vanderelst, 2009; Carr, Posner, Pollatsek & Snyder, 1979; Coltheart, 1978; Laszlo & Federmeier, 2007a; 2007b; 2008; Noice & Hock, 1987; Prinzmetal & Millis-Wright, 1984). The evidence accumulated so far indicates that despite the orthographic and phonological peculiarities of acronyms they are cognitively similar to mainstream words and that are processed in a similar manner, at least in the lexical tasks in which acronyms have been tested so far.

The letter identification task and letter string matching task are some of the tasks used to look at acronym processing. The identification of a given letter is commonly reported to be more successful when it is embedded in a mainstream word than when the letter appears in an illegal non-word (Reicher, 1969). Similarly, participants are faster to decide that two simultaneously presented strings of letters are the same if the stimuli are words than if they are illegal non-words (Carr et al., 1979). This is known as the word superiority effect (WSE). An acronym superiority effect has also been observed in both tasks with faster identification of letters within acronyms than within non-words and faster detection of similarities between two letter strings when these are acronyms than when they are non-words (Besner et al., 1984; Carr et al., 1979; Laszlo & Federmeier, 2007a; Noice & Hock, 1987). Prinzmetal and Millis-Wright (1984) used a version of the Stroop task to compare acronyms, mainstream words and non-words processes. Acronyms, words and non-words had each of their letters printed in a different colour ink. Participants were asked to name the colour of specific letters within the string. A greater number of errors were made in acronym and word trials than when the letters were embedded within non-words. More recently acronyms have been included in studies of word reading using the ERP technique (Laszlo & Federmeier, 2007b; 2008). The N400 component is a negative going deflection which is observed around 400ms after the presentation of a stimulus. The amplitude of the N400 elicited by a word is larger when it is first presented than when the same word is presented again. This repetition effect is shown in response to words but not when the stimuli are non-words. Laszlo and Federmeier (2007b; 2008) showed that a significant reduction in N400 amplitude was observable for acronyms. Importantly, closer examination of their data revealed that the repetition effect for acronyms was restricted to those items that the participants knew. That is to say that known acronyms showed word-like N400 repetition effects, while unknown acronyms elicited activity similar to non-words. In another recent study of acronyms, Izura and Playfoot (in press) investigated whether acronym naming times were not just similar to that of mainstream words but whether acronyms could be comparable to the way in which regular or irregular words are processed in the English language. The study assessed the influence of a number of variables on acronym naming using hierarchical regression techniques. The analyses showed a combined influence of variables commonly associated to regular and irregular word processing (e.g., number of letters, orthographic familiarity, printed frequency, age of acquisition, imageability, etc.). The authors conclude that acronym processing is not directly comparable to regular or irregular word processing but a complex mixture of both.

The studies reviewed so far indicate that the way in which acronyms and mainstream words are processed is similar overall but also that acronym recognition and naming has its own processing peculiarities, as reflected in the type of factors influencing their processing. Since the main motivation to study acronyms has been to determine whether the mental lexicon accommodates the distinctive orthographic and phonological configuration of acronyms, no research has examined the potential semantic singularity of acronyms. Thus, the present study is the first effort to fill this gap. Here, individuals were encouraged to process acronyms semantically using an acronym association task.

Although none of the research published so far has explored the semantic organization of acronyms, Brysbaert et al.'s (2009) study is the only one to date that when examining the potential similarity between acronyms and words emphasised meaning rather than form. They used acronyms in an associative priming paradigm which specifically relies on semantic links between the target and the prime. The common finding in priming tasks is that a response to a target word is affected by the characteristics of an item that precedes it (the prime), even if the prime disappears so quickly that it is not consciously detected. In Brysbaert et al.'s (2009) study, participants were presented with a lexical decision task in which word targets were preceded by briefly presented primes. In half of the 96 prime-target pairs the prime was an acronym, and in half the prime was a word. Each of the targets was presented twice, once preceded by a semantically related prime that could be an acronym (e.g., BLT-SANDWICH) or a word (e.g., FIB-LIE), and once with an unrelated prime (SNT-SANDWICH; HIM-LIE). Associative priming effects followed acronym primes as well as word primes. The facilitation resulting from acronym primes was observed irrespective of letter case. Thus, BLT, blt and bLt increased the speed of the response to the target by the same amount. Brysbaert et al. (2009) concluded that this finding was "particularly convincing for the lexical processing of acronyms" (pp. 1838).

As discussed above, the prevailing evidence indicates that acronyms are integrated in the mental lexicon along with mainstream words. However, their lexicality does not resemble that of regular or irregular words since processing differences have been detected (Izura & Playfoot, in press). No study so far has explored the semantic configuration of acronyms and assuming that it is the same as for mainstream words might be risky. In the present study we investigated the factors that might affect the speed with which acronyms are understood in an attempt to break the ice in the investigation of the semantics of acronyms.

The finding that associative priming effects are observed with acronym primes suggests that their meaning is accessed quickly. Semantic network models posit that words (and possibly acronyms) are stored as interconnected nodes (e.g. Steyvers & Tenenbaum, 2005). Each node has a number of other nodes linked to it and connections between nodes gain in strength every time they are used. Strong links are easy to access, and result in rapid activation. One technique used to examine semantic or lexico-semantic connections is the discrete word association task, in which participants are presented with a single word and required to produce the first word that comes to their minds. In order to achieve this, participants are forced to activate a second lexical representation which normally is semantically connected to the target word. It is argued that the participant's response is the word that has been activated quickest, and represents the strongest link between nodes (i.e., words) in the participant's lexicon. By asking a large number of participants to provide associations to the same cues, the way in which words might be semantically interconnected is inferred.

Word association data is rich in nature. Among other things it provides a measure of the strength of the link between cue and associate. Associative strength refers to the proportion of participants who produce the same response. For example, if 58 out of 100 participants said WHITE to the cue word BLACK, the associative strength between BLACK and WHITE is 0.58. Research suggests that associative strength is a reliable indication of the predominance of a particular response in the population (Nelson & Schreiber, 1992), and a good predictor of priming effects (Canas, 1990). Another common measure used in word association tasks is the number of different associative responses that are provided by more than one participant. This has been called *'meaning set size'* (Nelson & Schreiber, 1992). These two measures of associative response (i.e., associative strength and meaning set size) will be considered in the present study along with the following lexico-semantic characteristics of the cue words: word frequency, imageability, age of acquisition and letter length. The findings related to these variables and predictions are discussed in turn below.

High frequency words are recognised, produced, and recalled faster and with greater accuracy than low frequency words (Connine, Mullinex, Shernoff, & Yelen, 1990; Yonelinas, 2002). As studies have shown that most of the associative responses are semantically linked to the cue word (e.g., *computer* → screen), it is logical to think that word association requires word recognition, a process influenced by word frequency. It would be expected, therefore, that an influence of word frequency on word association responses would be observed. The literature seems to indicate that the frequency of the cue does have some impact on the strength and number of associations generated, but it is far from clear what this influence is. Early investigations indicated that high frequency cues elicited a stronger dominant response (i.e., produced by many individuals) than low frequency items, and fewer different responses overall (Postman, 1964; 1970). However, de Groot (1989) found no significant effects of the frequency of the cue word on the speed with which an associated word was produced, contradicting the predictions of semantic network models. Furthermore, both de Groot (1989, Experiment 7) and Brysbaert, Van Wijnendaele and De Deyne (2000) reported that high frequency cues elicited more diverse responses than low frequency cues. Interestingly, this was the inverse of the frequency effects reported by Postman (1964; 1970).

One major tenet of semantic network models is that the link between two concepts should be strengthened by its retrieval, thus the connections stemming from high frequency words should be particularly well-travelled. De Groot's study instead demonstrated that the imageability of a word was more important in the distribution and speed of word association responses. Imageability refers to the ease with which a word evokes a mental image (Paivio, Yuille, & Madigan, 1968). In discrete word association tasks, a smaller number of different responses are elicited by words which are highly imageable. Correspondingly, the dominant response to a high imageability cue word has a greater associative strength than that for a less imageable cue, and in addition, the responses are generated more quickly (Altarriba, Bauer, & Benvenuto, 1999; Brysbaert et al., 2000; de Groot, 1989). These findings were interpreted as evidence that the links between highly imageable nodes and related concepts were stronger than the links stemming from low imageable nodes.

Age of acquisition (AoA) refers to the moment in time in which words, objects and faces are first learned. The common finding is that objects, faces and words learned early in life are processed more quickly than those learned later (e.g. Brysbaert & Ghyselinck, 2006; Izura, Pérez, Agallou, Wright, Marín, Stadthagen-González, & Ellis, 2011; Morrison & Ellis, 2000; Pérez, 2007; Richards & Ellis, 2009). A current explanation for the AoA effect is the arbitrary mappings hypothesis (Ellis & Lambon Ralph, 2000). It states that the AoA effect is a product of the connections created during learning. When the relationship between input and output is predictable, a late acquired word can draw on existing knowledge to facilitate processing. In regular words, for example, the relationship of spelling to sound is consistent with other similarly spelled words (e.g., *sweet, feet*). Thus, a newly learned word can map on to existing representations (e.g., *tweet*). However, in irregular words the pronunciation is less predictable and the mapping is arbitrary (e.g., *yacht*). Under these circumstances late acquired words do not benefit from existing word knowledge and processing is relatively slow. The mapping between the written representation of a word and its meaning is even less predictable than the relationship between spelling and sound. Retrieving semantic information is, according to the mapping hypothesis, likely to be influenced by age of acquisition, and effects ought to be observed in the generating words in response to a cue as in Catling and Johnson's (2005) study. Catling and Johnson (2005) asked participants to produce a word from a semantic category (e.g. vegetables) that began with a particular letter (e.g. '*c*'). They reported that participants were significantly faster to provide early acquired words than late acquired words. Word association responses have also been shown to be affected by age of acquisition. Van Loon-Vervoorn (1989, cited by Brysbaert et al., 2000) showed that responses in a discrete association task were recorded reliably faster (240 ms) when the cue was early-acquired. Brysbaert et al. (2000) replicated Van Loon-Vervoorn's (1989) findings. They reported that early-acquired words elicited association responses 279 ms faster than late acquired words. Further, Brysbaert et al. (2000) provided evidence that there is greater agreement among participants in the associations generated for early-acquired words. Brysbaert et al (2000) pointed to the interpretation that the strength of the semantic connections from early-acquired word nodes is greater than from nodes for late-acquired words.

In sum, the study of the influence of the characteristics of the cue words on word association response times has the potential to inform about the strength and diversity of the semantic connections and with that shed some light on the structure of the semantic configuration of acronyms. It is important to note, however, that associative responses are not always semantic in nature. In fact a number of studies have devoted their attention to the nature of the relationship between a cue-word and its associate. Thus, word association responses have been grouped into three major categories depending on the relationship between cue-word and associative response (Fitzpatrick, 2006; 2007; 2009). These three groups are: *meaning-based associations* which have a semantic relationship with the cue-word (e.g., *bird-robin*);

position-based associations whose relation to the cue word is based in their frequency of co-occurrence in everyday language (e.g., *blue-moon*); and *form-based associations* are those that have an orthographic and/or phonological similarity (e.g., *plug-plum; chair-choir; air-heir*). Evidence shows that when individuals provide associative responses in their first language the majority of links between the cue word and a response are meaning based, while only very few associations responses tend to be based on the orthographic or phonological form (Fitzpatrick, 2006; Meara 2009). Importantly, when bilingual speakers are asked to provide associations in their second language (L2) the percentage of associative responses related in form to the cue word is higher than that produced in their first language, suggesting either weaker semantic connections for their L2 words or stronger form based relationships among their L2 words (Fitzpatrick & Izura, 2011).

The present study collected word association responses for the 146 acronyms described by Izura and Playfoot (in press) and examined the influence of associative strength, meaning set size, response category, word frequency, age of acquisition and imageability on the speed with which an associative response was generated. According to Steyvers and Tenenbaum's (2005) model, acronyms with high associative strength values will elicit faster responses because the connection between cue and response is strong in a large proportion of participants. It can also be predicted that responses will be quick for acronyms which elicit a large proportion of semantically related words. Finally, it is expected that the age of acquisition, imageability and frequency of an acronym cue will influence response latencies such that response times will be shorter for early acquired, high imageability and high frequency acronyms acting as cues.

Method

Participants

Fifty participants, 18 male and 32 female, were recruited for this study. The participants were students at Swansea University with a mean age of 22 years (range 19 - 29), and all were native speakers of English without reading deficits and normal or corrected to normal vision.

Materials

The 146 acronyms described in Izura and Playfoot (in press) were presented as cues in a discrete word association task. Values for imageability, age of acquisition, printed and rated frequency were selected from that database. There, imageability estimates were collected using the procedure outlined by Paivio, Yuille and Madigan (1969) by which participants were asked to indicate how easily each acronym evoked a mental image on a 7 point scale. Age of acquisition ratings were gathered following Izura, Hernandez-Muñoz and Ellis' (2005) procedure where participants wrote the age they were when they first learned the acronym presented. Rated frequency was assessed using a 7 point scale ranging from "rarely or never encountered" (1) to "encountered more than twice a day" (7). Printed frequencies were estimated on the basis of the number of hits returned by advanced internet search queries using the AltaVista search engine. This procedure has been shown to provide reliable estimates of frequency (Blair, Urland & Ma, 2002). The printed frequency values were transformed into their logarithm, base 10, plus one value.

Procedure

Stimulus presentation and randomization was achieved using E Prime software (Schneider, Eschman, & Zuccolotto, 2002). Acronyms were presented centrally in black ink on a white background and with Times New Roman font, size 12 points. Participants were informed that they would be seeing a list of acronyms, individually, and that they should say the first thing that came to their mind in response to each acronym. The instructions indicated that there were no right or wrong answers, and that it was important that responses reflected the first word they associated with the stimulus. Each acronym was presented individually in the middle of the computer screen and remained there until the participant responded. The verbal response from the participant was detected by a microphone placed approximately 10 centimetres in front of the mouth. This triggered the program to show a blank screen for 500ms and to record the time that had elapsed between the onset of the presentation of the stimulus and the detection of the response. Then a screen with a horizontal line in the middle appeared to signal participants to type in the response that they had just given. Participants could type their response in their own time and they were allowed to correct spelling mistakes if the wished to do so. Participants signalled that they had completed typing the word by pressing the return key. Then an asterisk appeared for 500 ms to indicate that the next trial was about to commence. All 146 acronyms were presented to every participant in a random order. The task took between 20 and 25 minutes to complete.

Results

Omissions were removed from the assessments of word association responses. Spelling mistakes and typographical errors were corrected only if the participant's intended response was clear (e.g. TNT – '*dinamite'*). If the response recorded was potentially a spelling mistake but made another word, this was not altered (MRI – scam) because of the difficulty of being certain of the participant's intention. Although it could be argued that the intended response is clear in this example, other instances were not so obvious. Therefore a consistent procedure was employed for all responses to all cues. The complete set of word association responses is included in the appendix.

Six participants offered association responses for fewer than half of the items presented, and were, therefore deleted from further analyses. Thus the analyses reported here are based on the responses from 44 participants. A multilevel or hierarchical regression analysis (Miles & Shevlin, 2001) was used here with RT as the outcome variable. The multilevel model is an extension of linear regression to allow variation between groups to be accounted for at different levels (Gelman & Hill, 2007). This offers an important advantage over classical regression in that systematic variation among the participants can be accounted for before assessing the variables under study. Essentially, each step of the hierarchy assesses whether newly entered variables are able to add to the variance in the outcome variable that can be explained by the model over and above that which was accounted for in the previous step. In this case, the participants were entered in the first level of the hierarchy. Important individual differences have been shown to occur in word association responses (Fitzpatrick 2007; 2009), so entering participants in the first step of the analysis partialled out the potential influence of individual differences on reaction times. In the second level of the analysis the proportion of responses that could be classified as semantic, position-based or form-based were included. The third level assessed the predictive power of associative strength and number of responses. The methods for determining these values are detailed below. The fourth and final step of the regression analyses included the following acronym characteristics, frequency, age of acquisition, imageability and letter length.

Categorisation of word association responses

Word association responses were classified into three categories according to the type of relationship that was found between the cue and the response produced. These categories were: form based, meaning based, and position based associates (Fitzpatrick, 2006). The meaning based category included responses that had a meaning relation with the cue word. Thus, synonyms (e.g. ASAP – quickly), acronym's complete or partial forms (e.g., ASAP – as soon as possible; KFC - chicken), hyponym s and co-hyponyms (e.g., RPG standing for rocket propelled grenade - rifle) and others (e.g., ECG – hospital or heart) were included in the meaning based category. Position based responses were those that frequently co-occur with the acronym in the natural language (e.g., SCUBA – diving). Associative responses were classed as form based when the response shared orthography or phonology with the cue, but not meaning. These were commonly instances where letters had been transposed (FBI – FIB), substituted (TFT – TNT), added (BST – best) or omitted (RNIB – nib).

Examination of the responses indicated that in some instances associations may have been made in two steps. For example, when presented with CCCP, eight participants responded with "camera." The participants could potentially have arrived at this response by a two stage process, first transforming CCCP to the orthographically and phonologically similar CCTV and then providing the constituent word "camera." Responses of this type were counted as a separate category and not included in the analyses presented here. Associations for which no clear discernible link between cue and response could be found were classed as erratic responses and removed from analyses. Circumstances where the participant had invented a new full form for the acronym were classified as erratic responses and also removed from further analyses. The total percentage of responses classified as members of each category are presented in Table 1.

(Table 1 about here)

As shown the majority of responses were meaning based, with only very few associations based on position or form alone. These response category measures were converted to proportions for inclusion in the multilevel regression. Thus, the number of semantic responses (33 for MMR) was divided by the total number of responses elicited by the acronym (37), making the proportion of semantic responses to MMR 0.89.

Associative strength and meaning set size

Associative strength refers to the proportion of participants who gave the most common response to each acronym. Singular (e.g. cat) and regular plural (created by adding an "s" as in cats) forms of a word were considered to be the same response. Irregular plurals were counted as a separate response. The frequency with which the dominant response was recorded by the participants was divided by the total number of responses to that cue to determine associative strength. For example, the most frequently given associate for BBC was "television" which was offered by 24 participants. All 44 of the participants recorded a valid associative response for BBC. Therefore the associative strength for "television" is 24 out of 44, or 0.55. The meaning set size was the total number of different responses given by two or more participants for each cue. This measure was also entered into the regression analysis.

Reaction time analyses

Response latencies for omissions (14%) were removed prior to reaction time analysis. Trials in which the voice key had malfunctioned (3%) were also deleted from these analyses. Correlations between the lexical variables (i.e., imageability, rated and printed frequency, age of acquisition and letter length), the measures indicating the type of link between cue and response (i.e., meaning, position and form based), the measures of response distribution (i.e., associative strength and meaning set size) and RTs are presented in Table 2.

(Table 2 about here)

Significant correlations were found between all of the predictor variables and RT, with the exception of printed frequency and number of position responses. Acronyms which were high in rated frequency, high imageability, early acquired or lengthy generated association responses more quickly than their short, low frequency, low imageability or late acquired counterparts. This supports the findings of de Groot's (1989) and Brysbaert et al.'s (2000) association studies using mainstream word cues. In relation to the proportion of responses which could be classified in each category, significant correlations were observed with all other variables. The only exceptions to this were the non-significant correlations between position and length, position and age of acquisition and form and printed frequency. Associative strength was significantly correlated with all other variables, and meaning set size correlated with all but printed frequency. Finally, the correlations between pairs of predictor variables were all significant, and mirror the general relationships between these variables in mainstream word studies (e.g. Balota et al., 2004).

For the purpose of all analyses reported here, acronym naming times were log transformed to reduce skew. Multicollinearity of the predictor variables was assessed in relation to the variance inflation factor (VIF). VIF values were within the acceptable range (1.04 to 3.30). Beta coefficients for each of the predictor variables are presented in Table 3.

(Table 3 about here)

In step 2, the proportion of responses that were linked to the cue acronym semantically or in terms of their form significantly predicted reaction times. Responses were likely to be fast for cues which elicit a high proportion of semantic responses and slow in cues with high proportions of form links. In step 3, both associative strength and meaning set size were predictive of reaction times. Particularly strong and commonly generated links between cue and response were given quickly. Responses were generally slow when a large number of different associations were recorded for the same cue. Imageability, age of acquisition and length emerged as significant predictors of word association response latency in step 4. As a whole, the regression model was able to account for 24% of the variance in RT.

Word association has traditionally been considered a semantic task (Brysbaert et al., 2000). This is clearly the case in this study given that the majority of the responses are semantically related to the cue word (94%), and suggests a good level of acronym knowledge among the participants in this study. However, as mentioned in the introduction, not all responses in word association tasks are semantic, since some of them appear to be the result of co-occurrence of cue and response, and others share only their orthographic form. In order to give a purer assessment of the lexical factors affecting semantic access for acronyms, the influence of the lexical variables on reaction times was reassessed, this time taking into account only those responses that were semantically linked to the cue. The results of the multiple regression analysis carried out are presented in Table 4. When considering only semantic responses, age of acquisition and imageability were the only significant predictors of reaction times. The proportion of the variance accounted for by the model increased to 42%.

(Table 4 about here)

Discussion

The present study investigated the influence of a number of lexico-semantic factors on acronym association response times. Two analyses were carried out. The first analysis used a multilevel regression technique to take into consideration the variance associated with individual differences and to observe the influence of the selected predictors at three different levels of analysis. Individual differences were entered in the first step of the analysis. In the second step the influence of the type of link between cue and response was examined while the predictive power of two response distribution measures (i.e., associative strength and meaning set size) and acronym characteristics were entered into the third and fourth steps of the analysis respectively. Responses were made quicker to cues that: 1) elicited a large proportion of semantic responses, 2) a low proportion of form responses, 3) were high in associative strength, 4) were low in meaning set size, 5) were long, early acquired and imageable. The second analysis used multiple regression analysis to consider the influence of lexical variables on RTs for only those responses that were semantically linked to the cue. As in previous reports, participants were shown to be faster to respond to cues which were imageable and early acquired (Altarriba et al., 1999; Brysbaert et al., 2000; de Groot, 1989). A higher proportion of the variance in RT was accounted for when only lexical factors and semantic responses were considered, implying that the factors considered were better at explaining the variance associated to semantic than to any other response. It is important to note that among the factors considered, imageability and age of acquisition were the only significant predictors for associative responses linked to the cue by meaning.

It is worth noting that as in studies with mainstream words the majority of responses elicited in a discrete association task using acronyms were related to the meaning of the cue (Fitzpatrick, 2006). In contrast only a small proportion of word association responses were form based and an even smaller proportion of responses were position based (i.e., responses that often co-occur with the target). Interestingly, this is closer to the pattern of associative responses produced to mainstream words by second language speakers of English than those produced by first language speakers (Fitzpatrick & Izura, 2011). Thus, in the first language there are more position than form based responses while the reverse is the case in the second language. This might suggest that the semantic connections of some acronyms are weak or not very stable as it also happens for some second language words. On those occasions individuals used the potentially stronger lexical connections providing associative responses that shared the form rather than meaning. The scarcity of position based responses might reflect the fact that the use of acronyms is not as profuse as that of mainstream words.

In relation to the response distribution measures, meaning set size and associative strength, the present study replicate and extend on previous findings reporting semantic effects on word recognition times. Associative strength and meaning set size affected response association times as it has also been reported to affect word recognition times (Balota et al., 2004; Buchanan, Westbury & Burgess, 2001). The fact that words with large meaning set sizes generated slower responses might be related to a similar result found by Mirman and Magnuson (2008) where individuals were slower at discriminating words with many near neighbours (i.e., words that had a closer semantic distance with the cue word) and is congruent with the finding of faster response times for words with high associative strength and therefore low in meaning set size.

One finding of particular interest is that word association responses did not correlate with or show a significant effect of printed frequency. The nature of acronym creation and use may be responsible for the lack of correlations with printed frequency. The correlation between rated and printed frequency in the acronyms was significant, but relatively low at .34. Acronyms are created to abbreviate cumbersome or technical phrases, and often come from highly specialised fields. As a result acronyms with high printed frequencies may not necessarily be high frequency to all the participants. It is suggested, therefore, that the non-significant correlations with printed frequency indicate that printed frequency measures for acronyms may not equate to individual experience. Considering the word association task is mainly a semantic task, knowledge of the meaning of an acronym is integral to the successful completion of the task. The fact that rated frequency correlated significantly with several aspects of word association behaviour is interpreted as evidence that subjective or rated frequency estimates are, for acronyms at least, a better representation of lexical knowledge than the printed frequency measures. Rated frequency is more likely to reflect the level of familiarity that undergraduate students have with the items. However, once entered into the regression analyses neither rated nor printed frequency was a significant predictor of word association RT. This finding supports the interpretation of de Groot (1989) that frequent encounters with words and their assumed automatic distributed activation to related representations might not be sufficient to strength those connections. It suggests, in addition, that the frequency of a word is not as relevant when providing associative responses as age of acquisition, letter length and imageability are.

Interestingly an effect of word length was observed when all the responses were considered but not when only the responses related in meaning to the cue word were analysed. This seems to be the result of an interaction between word length and the type of link between the cue acronym and the response, with length effects having a significant influence over form based responses but not so much over semantically related responses. This might be because longer acronyms are more likely to look like words and therefore generate rapid responses orthographically similar.

Regression analyses showed that imageability was a significant predictor in the two regression models. De Groot (1989) found that imageability was an important factor in RT and associative strength in a mainstream word association task. De Groot (1989) argued that highly imageable words have relatively strong connections with at least one associated node and that these strong links are shared by a large number of individuals. Thus, the associated concept is retrieved quickly and the same associate is offered by a larger number of participants. The same interpretation would appear to apply in the present study. That said the potential semantic complexity of acronyms may benefit from considering other measures of semantic richness such as those discussed by Pexman, Hargreaves, Siakaluk, Bodner and Pope (2008) in future studies. Pexman et al. (2008) studied three measures of semantic richness; 1) number of features in a concept, 2) semantic neighbourhood or the number of words that co-occur in similar contexts and, 3) contextual diversity referring to the extent to which a word is distributed into nine different content areas. They highlighted that each of these measures had previously been demonstrated to affect latencies in word recognition tasks. Pexman et al. (2008) showed that while the three measures had an effect in lexical decision times only number of features and context distribution had an effect in a semantic categorization task. Unlike the present study, however, Pexman et al. (2008) did not control for age of acquisition or imageability. It would therefore be worthwhile investigating the predictive power of semantic neighbourhood, number of features and contextual diversity would be predictive of the speed with which associative responses are generated for acronyms once age of acquisition and imageability are controlled for.

Another important finding is the age of acquisition effect observed when all responses were taken into account (analysis 1) and when only the semantic responses were considered (analysis 2). This finding echoes the age of acquisition influence previously shown in word association tasks. Both van Loon-Vervoorn (1989) and Brysbaert et al. (2000) reported that early acquired words were quicker to produce an association response than words acquired later in life. In addition, Brysbaert et al. (2000) also found a significant effect of age of acquisition on their measure of associative strength. The authors suggested that influence of age of acquisition and imageability on word association had a similar source. Brysbaert et al. (2000) proposed that late acquired words are learned by relating the new 'late' concept to a previously existing word representation. As a result of this learning process the representations for early acquired words are accessed more often, and therefore the links to and from an early acquired node are stronger than for late acquired words. The age of acquisition effects shown in the present study could be the result of a difference in the speed with which early and late acquired acronyms are recognised and the relative strength build in the intra-lexical links. However, the fact that the predictive power of age of acquisition increased when only semantically linked responses were considered suggests that age of acquisition may be a semantic property as suggested by van Loon-Vervoorn (1989) and Brysbeart et al. (2000). Nevertheless, Izura and Ellis (2002; 2004) showed that second language speakers of English were faster at processing words that had been learned early in the second language than words learnt some time later. This occurred even when the early acquired word in English as L2 was a late acquired word in Spanish as L1 and vice versa (e.g., *money* and *travel,* are late learned words in L1 but useful and early acquired in L2 while *witch, fairy* are words incorporated early in the L1 vocabulary but late in L2). Considering these reports we are inclined to think that the age of acquisition effect found in the word association task emerges from the lexico-semantic connections that might exist between representations (Ellis & Lambon-Ralph, 2000; Steyvers & Tenenbaum, 2005).

This study has provided useful information concerning the concepts commonly associated with acronyms. Further research using acronyms and mainstream words in a word association paradigm could directly compare the similarities and differences between the two types of lexical items. Here it has been shown that associative responses to acronyms in English as a first language have patterns similar to those produce by English second language speakers and are in addition influenced by age of acquisition and imageability.

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Appendix

Acronym cues used in the word association task.

ABBA	CBT	FBI	KFC	OHP	SPSS

ACDC	CCCP	FIFA	LBW	PAYE	STD
ADHD	CEO	FYI	LCD	PDA	TBA
AGM	CIA	GBH	LMAO	PDF	TCP
AOL	CJD	GCSE	LSD	PGCE	TFT
APR	CNN	GMT	MBA	PSP	TLC
ASAP	CPU	GPA	MDMA	PTA	TNT
ASBO	CSI	GPS	MGM	PTO	UCAS
ATM	DHL	HDTV	MMR	PTSD	UEFA
AWOL	DIY	HGV	MRI	PVC	UFC
BAFTA	DNA	HIV	MRSA	QVC	UFO
BBC	DOA	HMO	MSN	RAF	UHF
BHS	DOB	HMS	MTV	RBS	USA
BLT	DUI	HMV	NASA	REM	USB
BMI	DVD	HRT	NASCAR	RNIB	USSR
BMW	DVLA	HSBC	NATO	RNLI	VCR
BNP	DVT	IBM	NBA	RPG	VHS
BOGOF	ECG	IBS	NCIS	RRP	VIP
BPM	EEG	ICT	NHS	RSPB	WWF
BPS	ENT	IMDB	NSPCC	RSPCA	YMCA
BRB	ESP	IRA	NYPD	RSVP	
BSE	ESRC	ISP	OAP	SAE	
BST	ETA	ITN	OBE	SAS	
BTW	FAO	ITV	OCD	SCUBA	
BYOB	FAQ	IVF	OCR	SMS	

Table 1 – Percentage of word association responses in each cue-response category, along with mean and standard deviation of response types per cue.

	Total percentage	Mean number per cue	Standard deviation
Semantic	94	30.96	8.83
Position	< 1	.30	.89
Form	6	1.73	2.83

Table 2 – Correlations between predictor variables and reaction times

	Rated Frequency	Printed Frequency	Age of Acquisition	Imageability	Letter Length	Semantic Relation	Position Relation	Form Relation	No of ass. Responses	RTs
Ass. Strength	0.17**	0.07**	-0.25**	0.34**	0.22**	0.14**	-0.15**	-0.27**	-0.64**	-0.14**
Rated Frequency		0.34**	-0.17**	0.57**	-0.11**	0.30**	0.19**	-0.28**	-0.24**	-0.09**
Printed Frequency			-0.03*	0.11**	-0.36**	0.06**	0.06**	n.s	n.s	n.s
Age of Acquisition				-0.55**	0.03*	-0.18**	n.s.	0.18**	0.39**	0.15**
Imageability					0.10**	0.55**	0.06**	-0.44**	-0.44**	-0.18**
Letter Length						0.05**	n.s.	-0.14**	-0.07**	-0.05**
Semantic Relation							-0.14**	-0.40**	-0.24**	-0.08**
Position Relation								-0.06**	0.17**	n.s
Form Relation									0.32**	0.09**
No of ass. responses										0.20**

Note: * $p < .05$ ** $p < .001$ n.s. non-significant. RT = reaction times. Freq = frequency. Ass = Associative. No = Number

Table 3 – Beta coefficients for each predictor in the multilevel regression analysis

		β
Step 2	Semantic links	-.077**
	Position links	.019
	Form links	.056**
	Adjusted R^2	.184**
Step 3	Associative Strength	-.037*
	Number of responses	.191**
	Adjusted R^2	.224**
Step 4	Rated Frequency	-.024
	Printed Frequency	.000
	Age of Acquisition	.053*
	Imageability	-.091**
	Letter Length	-.036*
	Adjusted R^2	.236**

* p < .05 ** p < .001

Table 4 – Beta coefficients for predictor variables when only RTs to semantically related responses were considered

	β
Rated Frequency	.004
Printed Frequency	.132
AoA	.256*
Imageability	-.462**
Letter Length	-.100
Adjusted R^2	.416**

* $p < .05$ ** $p < .001$